Michigan Department of Agriculture

Generally Accepted Agricultural and Management Practices for Cranberry Production

June 2006

Michigan Commission of Agriculture
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Cranberry – June 2006

In the event of an agricultural pollution emergency such as a chemical/fertilizer spill, manure lagoon breach, etc., the Michigan Department of Agriculture and/or the Michigan Department of Environmental Quality should be contacted at the following emergency telephone numbers:

Michigan Department of Agriculture: 1-800/405-0101
Michigan Department of Environmental Quality: 1-800/292-4706

If there is not an emergency, but you have questions on the Michigan Right To Farm Act or items concerning a farm operation, please contact the Michigan Department of Agriculture, Right To Farm Program, P. O. Box 30017, Lansing, Michigan 48909, (517) 373-9797.

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PREFACE

The Michigan legislature passed into law the Michigan Right to Farm Act (Act 93 of 1981) which requires the establishment of Generally Accepted Agricultural and Management Practices (GAAMPs). These practices are written to provide uniform, statewide standards and acceptable management practices based on sound science. These practices can serve producers in the various sectors of the industry to compare or improve their own managerial routines. New scientific discoveries and changing economic conditions may require necessary revision of the Practices.

The Generally Accepted Agricultural and Management Practices that have been developed are the following:

1) 1988 Manure Management and Utilization
2) 1991 Pesticide Utilization and Pest Control
3) 1993 Nutrient Utilization
4) 1995 Care of Farm Animals
5) 1996 Cranberry Production
6) 2000 Site Selection and Odor Control for New and Expanding Livestock Production Facilities
7) 2003 Irrigation Water Use

These practices were developed with industry, university and multi-governmental agency input. As agricultural operations continue to change, new practices may be developed to address the concerns of the neighboring community. Agricultural producers who voluntarily follow these practices are provided protection from public or private nuisance litigation under the Right to Farm Act.

The website for the GAAMPs is at http://www.michigan.gov/gaamps.

Section I. INTRODUCTION

Michigan has the climate, soils, and processing infrastructure necessary to support a cranberry industry. High market demand and price have stimulated interest in cranberry production outside traditional cranberry producing areas. Several individuals have recently begun growing cranberries in Michigan; numerous others are considering this crop, and Michigan cranberry production is expected to increase over the next few years.

The cranberry plant is a wetland crop species (an obligate hydrophyte) that is grown commercially in natural or artificial wetlands managed for crop production. Since cranberry production is a water dependent activity, many unique cultural and management practices have been developed for their production. Five to ten acre-feet of water may be needed annually per acre of cranberry bed. Farming within a wetland environment presents considerable potential for adversely affecting existing natural resources or the function of those resources. Cranberry producers need to minimize these risks by utilizing environmentally sensitive and sound management practices.

Cranberries are commercially produced in the mild marine climate of western Oregon and Washington, the moderate climate of Massachusetts, New Jersey and Maine, and the harsh continental climate of Wisconsin. Some management practices differ from one region to another to reflect these climatic differences. For example, winter flooding and ice cover is a necessity in Wisconsin, but no winter protection is required in Oregon and Washington. Some characteristics of Michigan's climate fall between these extremes, therefore, Michigan growers may eventually find that management practices employed in other states may not be completely suited to all areas of Michigan. Recommendations for commercial cranberry production in Michigan will likely change as the industry develops and gains on-farm experience and as technology changes.

These Generally Accepted Agricultural and Management Practices (GAAMPs) were developed as a result of a Memorandum of Agreement between the Michigan Department of Agriculture (MDA) and the Michigan Department of Environmental Quality (MDEQ). These agencies have a mutual interest in the development of a viable cranberry industry in Michigan, and are dedicated to protecting environmental quality. The GAAMPs are intended to provide technical and regulatory guidance that is economically viable and environmentally sensitive. Farm operations voluntarily following these GAAMPs will be provided nuisance litigation protections and other provisions pursuant to the Michigan Right to Farm Act, Public Act 93 of 1981, as amended. The Michigan Commission of Agriculture has the responsibility to define GAAMPs under the act and has identified the need for these GAAMPS to address the unique issues relative to cranberry production. GAAMPs will be reviewed annually and revised by the Commission when necessary.

Section II. SITE SELECTION

Nearly all regions of Michigan meet the climatic requirements of cranberries. However, it is necessary that cranberry production operations be located in sites with proper soil and hydrologic conditions for successful commercial production. These conditions will directly influence the design, construction and operational costs of the farming operation. Because cranberries require the existence or establishment of wetland conditions and large quantities of water, certain regulatory requirements may also need to be met for a specific site. Site selection, farm design, construction of beds and associated facilities, and operational activities must take into account the federal, state and local regulatory requirements. The presence of regulated wetlands and water bodies within, or adjacent to, a site considered for cranberry production, and possible permit requirements regarding wetland alterations should be considered, and may influence site selection, as well as farm design and placement and construction of cranberry beds, reservoirs, dikes and associated management facilities.

- **Sites need to meet the soil and water requirements of cranberries.**
  Cranberries require a growing media of sand or organic soil with an acidic pH (below 5.5). Higher pH materials are suitable if pH can be reduced economically. A nearby source of suitable sand is needed for construction and future sanding practices. Hydrologic and soil characteristics should provide the capacity to maintain the water table at or near the bed surface. Preferred sites also have minimal slope, since flat areas generally require less earth moving to develop. A ready supply of water is needed, which is physically and legally usable. Water with an acidic pH is preferred. More detailed cranberry site selection considerations are provided in Appendix III. USDA Natural Resources and Conservation Service (NRCS) can provide copies of local soil surveys and other soils data.

- **Regulatory requirements must be met.**
  Site selection, farm design, construction and operational activities must take into account the regulatory requirements, which may be necessary from federal, state and local agencies, and Tribal laws and regulations. Prior to establishing a cranberry production site, producers should consult with the Land and Water Management Division of MDEQ and all other appropriate agencies to determine if any permits are required. All required permits need to be obtained prior to initiation of any regulated activities, such as, construction of cranberry beds and associated facilities. Regulatory requirements are described in Appendix II. Early contact will advance the identification of possible permit requirements and the application review process. The MDA Environmental Stewardship Division and Michigan State University Extension may also be helpful in identifying potential sites.

  The selection of a site for growing cranberries which recognizes environmental concerns along with proper farm design and operation will ease compliance with applicable regulatory requirements. A qualified environmental consultant who is familiar with regulatory requirements may be helpful in the site selection and design process. The grower or their consultant should contact the regulatory agencies in the

initial stages of site selection and design of the farm operation.

The following information on site selection is provided to help identify locations that either do not require a wetland or other state permit(s) for development, or represent sites that are more acceptable under MDEQ and federal permit review criteria.

A. Sites which are considered either upland sites or prior wetland areas that have previously been drained for agricultural use and no longer meet the definition of a wetland. These are the more desirable sites for cranberry development and do not require a wetland permit for bed development but may require other local, state or federal permits. In a number of regions in Michigan, former wetland areas with suitable soils have been drained for agricultural use and may be suitable for cranberry growing if steps are taken to restore the high water table (e.g. placement of water control structures on drainage outlets) and other criteria are met.

B. Sites having soils which have been drained for agricultural use but which do meet the state and federal definitions of a wetland. These sites require permits for construction of cranberry beds and associated facilities. However, permits will be issued unless other resources would be adversely impacted by the proposed conversion. For sites which are still technically a wetland, but which have reduced wetland values due to past or current agricultural drainage, MDEQ wetland review criteria will not be more stringent than federal permit requirements. MDEQ will issue wetland permits for these sites as long as other resources would not be adversely impacted. The applicant will need to minimize wetland impacts and should locate support facilities within upland areas where feasible.

C. Permits are required for construction of cranberry beds in natural, undisturbed wetlands. Permit requirements will be consistent with federal programs regarding construction of cranberry beds in natural, undisturbed wetlands, and will weigh the impacts and benefits of the proposed project.

MDEQ will evaluate all potential sites for cranberry development on a case by case basis, including sites that do not clearly meet the above categories.

Section III. DESIGN AND CONSTRUCTION OF CRANBERRY FARM OPERATIONS

An economically feasible and environmentally sound cranberry farm operation depends on appropriate planning for facility design and construction activities. The NRCS provides useful information on most aspects of design and construction for erosion and sedimentation control. The Conservation Practice Standards and Specifications are contained in the NRCS

electronic Field Office Technical Guide (FOTG). Technical assistance may be obtained from local NRCS or Conservation District offices or private-sector professional engineering firms or technical service providers.

- **Cranberry beds need to meet the growth requirements of the plants and facilitate management.**
  Arrangement, dimensions and elevations of beds depend on the topography and other site characteristics. Construction procedures are site specific, but some general steps are followed. To construct cranberry beds, the surface soil is usually removed and, if suitable, often used to build dikes and roads. In most cases, clean sand is spread over the bed, and the surface is leveled. Drainage ditches are usually dug around the perimeter of the beds. Subsurface (tile) drain and pumping plant for water control may also be installed.

- **Water management facilities need to meet the annual water requirements.**
  A detailed water budget should be calculated to help insure an adequate and timely water supply. An example of a water budget evaluation is provided as Appendix IV. Ponds are usually constructed to serve as water reservoirs. Wells may supplement the water supply. Various drainage ditches, dikes, canals, bulkheads and irrigation and drainage systems are usually installed to move water to and away from beds.

  All new cranberry growers should consider designs that allow for water recycling. These systems are referred to as "closed systems" because surface runoff and drainage water from the beds is retained and later reused. Properly managed closed systems can provide a higher level of environmental protection.

  Closed systems usually have an upper reservoir that serves as the water source, and a lower recovery reservoir. It is desirable to have the beds at a lower elevation than the water source. Water is temporarily stored in the down slope reservoir where potentially nutrient-bearing sediments are trapped and some breakdown of pesticides occurs. Generally, water levels in the down slope reservoir should be kept low when pesticides are applied. Pesticide residues moving out of beds in the drain water can then be retained and degraded in the down slope reservoir. This will help to protect groundwater and surface water quality. This water can also be pumped back into the beds or an upslope reservoir and reused. Recycling water in this manner reduces the water capacity required in the upslope reservoir and the need for water from other sources. In sites where a large amount of surface water runoff from higher land may inundate the bed area, diversion ditches may channel excess water from the beds.

  Cranberry operations that divert surface water runoff, and drainage water from beds to streams or other surface water bodies (and do not collect and recycle water) are called "open systems". After a pesticide application, any water in the treated area needs to be held for no less than the time indicated on the pesticide labels before it can be released. Open systems have a greater potential than closed systems to adversely affect the environment. The design and management of an open system should

minimize the potential for adverse environmental impacts.

- **Control soil erosion and sedimentation during construction.**
  Soil erosion control is an important component of agricultural non-point source pollution prevention programs because soil itself can be a pollutant and may be a carrier of pollutants, such as adsorbed pesticides and nutrients. Avoid disturbing soil during heavy rain or wind storms. Blowing dust and wind erosion can be reduced by sprinkling water on dry soil or sand. Excavated sand should be stockpiled away from open water. Consider lining stream and ditch banks with silt fences to prevent sedimentation. Grass or vegetation should be established on roadways, dike roads, etc. as soon as possible to reduce the likelihood of soil erosion.

Section IV. WATER MANAGEMENT

Water is essential to cranberry production; it is used for spring reflow, frost protection, irrigation, harvest, and winter protection. Depending on the site, water may be obtained from sources such as lakes, rivers, streams, drains, or reservoirs, as allowed by law. Water movement in and out of beds is controlled by a system of dikes and ditches. Excessive water may be drained or pumped to various water recovery or release areas.

- **Dikes, ditches, reservoirs and flumes should be maintained**.
  Dikes control water movement and support production equipment. Since wind, water, and burrowing animals deteriorate dikes, maintenance and upgrading are essential for efficient water containment and movement, and safe vehicle passage. Burrowing animals are the primary cause of dike failure, and must be controlled. Establish grass or other vegetation on dikes and ditch banks to stabilize the soil. However, vegetation should be mowed so that it does not produce seed and increase weed pressure in the beds. Ditch bank erosion commonly occurs when saturated, unstable soil materials are subject to high velocity water flow. Erosion can be reduced by installing geofabric or geogrid material, rock cover or riprap to unstable embankments and down gradient sides of flumes, and by lowering water levels in ditches to improve bank stability during periods when the soil is wet because saturated soil has little strength. Designed soil erosion control practices, such as those identified above can be requested from the NRCS and the local Conservation District or technical service providers.

  Private ditches and waterways need to be free of excessive vegetation and sedimentation that can impede drainage. If beds have adequate soil drainage, some live aquatic vegetation left in the ditches during the growing season may help filter nutrients and pesticides from the water. In this case, delay cleaning ditches and waterways until later in the season, to take full advantage of this filtering action.

When cleaning private ditches, ponds or reservoirs, be careful not to undercut ditch banks or to dig ditches too deep, since undercutting leads to instability and bank failure. If sediment being dredged from ditches has a fine texture, consider using a silt fence to trap sediments before they move offsite. Cleaning ditches from the point most distant from the flume (moving towards the flume) will enhance sediment settling. Dispose of spoils on established dikes or other upland areas. Allow ample time for excess water to drain out of dredged sediments before being moved. Use silt fences to keep sediments contained. Growers should employ all reasonable sediment control and removal techniques to receive and cleanse waters exiting the bed. Growers should also consider diverting sediment-charged water to holding ponds to allow settling of solids.

Worn or damaged flume or bulkhead boards should be replaced regularly to prevent the escape of ditch or flood water. Keep boards free of debris and consider using rubber gasket strips on channel guides or a tension activated tie down system to decrease leakage. Consider locking flume or bulkhead boards in place.

- **Reduce ditch water levels as much as possible before applying nutrients and pesticides.**
  Lower water levels in ditches before applications to allow for absorption of nutrients and pesticides into ditch sediment and vegetation, and increase water holding time.

- **Adequate drainage is needed in all beds.**
  Proper soil drainage is needed for healthy vines. Healthy vines may require less fungicide because they are less prone to diseases such as root rot. Drainage may be improved by installing surface drainage, main or laterals or subsurface (tile) drains, or by winter sanding.

- **Anticipate weather.**
  Heavy rainfall can wash nutrients, especially nitrogen and pesticides off the target area. Follow weather forecasts and halt fertilizer and pesticide applications when rainstorms are forecasted or frost protection is required.

A. IRRIGATION

Sprinkler irrigation is essential for cranberry culture to protect plants from spring and fall frost damage, supply water during the growing season, and apply nutrients and pesticides. To perform these functions effectively, irrigation systems should be engineered and maintained to provide maximum water application uniformity.

- **Irrigation systems should be designed for uniform water application.**
  Irrigation systems should deliver uniform application rates of 0.1 to 0.15 inches per hour. To optimize uniformity, reduce system pressure losses by protecting pipes from dents and limit the number of 90º elbows. Reduce plugging by installing clean out

plugs at lateral ends and a strainer basket on the intake pipe. Secure risers to a vertical stake to limit wobble. Straight, stationary risers provide more uniform water application.

- **Irrigation equipment should be maintained in effective operating condition.** Follow manufacturer recommendations for pump, valve and sprinkler head maintenance. Inadequate maintenance can result in breakdowns at critical times, reduced system uniformity, and inappropriate application rates. Precautions should be taken to prevent fuel leaks or spills.

- **Irrigation application rates and uniformity should be tested periodically.** Irrigation system uniformity should be tested regularly. Systems with low uniformity cause some areas to receive adequate water while others receive too little or too much. Coefficient of Uniformity (CU) of less than 60% indicates the system needs updating or was not properly installed. The NRCS recommends a CU of 85%, an attainable goal using current technology. Uniformity may be affected by sprinkler rotation speed, pattern type and spacing (closer spacings give higher uniformities), nozzle pressure, wear and size, different trajectory angles resulting from leaning risers, friction losses in laterals, different sprinkler elevations, and wind. Data collected from an Irrigation Uniformity test can be used to calculate the system's irrigation rate and modifications can be made by changing operating pressure or nozzle size.

- **Irrigation should be applied at appropriate rates and intervals.** Newly set plants should receive frequent, light applications of water for the first two weeks or until roots form. To promote deeper rooting irrigate newly planted beds less frequently but longer after plants become established. Established beds require 1 to 2 inches of water per week. Irrigation rates should be reduced to reflect rainfall received in lieu of irrigation water. Apply up to 0.5 inches per irrigation event.

  Irrigation should be used to cool plants when ambient air temperatures reach 85^{o}F or higher. Cool plants by irrigating for about one hour to thoroughly wet the plants and soil surface. Irrigate again when temperatures rise to 85^{o}F. Drain surface pipes between irrigations to prevent scalding caused by hot water in pipes.

  When irrigating for frost control, monitor both temperature and growth stage, since lethal temperatures vary with growth stage. Begin irrigating when temperatures at bed level are 1-2 degrees above the critical temperature, and stop irrigating when temperatures rise safely above the critical temperature. Effective frost protection requires irrigation rates of at least 0.1 inches per hour. This rate protects buds and fruit to a temperature of 20º F (under wind conditions of 0 to 1 mph). Sprinklers should rotate at least once per minute to provide frost protection.

B. FLOODING

Cranberry beds are flooded in the fall to harvest berries, after dry harvest to remove trash and debris, during the winter to protect plants from cold injury, and in the spring to control some pests, remove the frost from the soil, and protect plants from severe freezes.

- **Harvest**
  Hold harvest flood water in beds for at least one day and then slowly pump or drain the water from the beds.

- **Winter Flooding**
  The cranberry is an evergreen plant that can be damaged by cold and fluctuating temperatures. Beds are usually flooded in early winter so that ice covers the plants and protects them from cold, windy weather. This ice layer also makes it possible to apply sand.

  Winter flood water should be applied when the surface layer of soil has frozen. The water needs to come from a surface source rather than ground water. Having the ground frozen decreases the potential of losing flood water through seepage. Using surface water that is already near freezing also reduces the chance of removing frost from the ground. The winter flood should be applied as quickly as possible without causing soil erosion. Fast flooding reduces the chance of the wave action of the water pulling out the plants.

  Drain flood water slowly so as to minimize water fluctuations and sedimentation in water recovery or release areas.

Section V. NUTRIENT MANAGEMENT

Cranberry beds require fertilizer applications to produce economic yields. However, nutrients such as nitrogen (N) and phosphorus (P) can harm water quality if not managed properly. Excessive use of fertilizers can injure cranberry plants and reduce yields. Refer to the GAAMPs for Nutrient Utilization, Michigan Commission of Agriculture, for general information on how fertilizers should be handled and used to minimize environmental impacts. Refer to university recommendations for guidance on fertilization practices.

- **Nutrient use should be based on plant performance, tissue analysis and soil test results.**
  Beds on organic soils may require as little as 10 lb N per acre per year, whereas those on sandy soils may need as much as 60 lb per acre. Determine the appropriate rate for specific beds based on vine growth and yields, tissue N levels, and previous

fertilization practices. Refer to the Compendium of Blueberry and Cranberry Diseases (APS Press) for descriptions of nutrient deficiency and toxicity symptoms.

- **Plan fertilizer applications to correspond with crop demand.**
  Fertilizers containing N and P should be applied between bud break and late August, when plants are most able to utilize nutrients. This reduces chances of N or P loss to the environment. Fall or early spring applications of fertilizer increase the risk of nutrient losses through leaching, and should be avoided. Potential for leaching is greatest on coarse textured soils. Lower rates applied when the plants are able to use the nutrients reduce runoff potential and increase nutrient efficiency.

- **Ammonium forms of N should be used.**
  Cranberries prefer ammonium-N over the nitrate form. Ammonium-N adsorbs to clay and organic matter in the soil, so it is less mobile than nitrate-N, and less prone to leaching.

- **Fertilizer application equipment should be calibrated.**
  Fertilizer is applied to cranberry beds with spreaders or booms, airplanes or helicopters, or through irrigations systems. All application equipment should be calibrated according to the manufacturer's recommendations to insure the proper amount of fertilizer is applied.

- **Direct application of fertilizers to open water on cranberry beds should be minimized.**
  When applying fertilizer to cranberry beds through irrigation systems, use part-circle sprinklers or sprinkler guards to minimize fertilizer applications to open water on cranberry beds which can result in off-site movement.

- **Soil pH should be maintained in the proper range.**
  Nutrient utilization and plant growth are optimized when soil pH is between 4.0 and 5.5. Additions of sulfur may be needed to keep soil pH sufficiently low. Sulfuric acid may need to be added to irrigation or flood water that is high in alkalinity. Water discharged off the site should be in compliance with water quality standards. Safety precautions should be followed to prevent inadvertent contact with concentrated sulfuric acid.

Section VI. INTEGRATED PEST MANAGEMENT (IPM)

Commercial cranberry production requires management of insect pests, diseases and weeds. IPM integrates biological, cultural and chemical control practices to manage these production problems. IPM requires knowledge of pest life cycles and identifying characteristics, and an understanding of all available control options. By scouting cranberry beds and understanding pest biology and control options, growers

are able to make appropriate pest management choices. Useful references may be found in Appendix I.

A. PESTICIDE APPLICATIONS AND HANDLING

The current version of the GAAMPs for Pesticide Utilization and Pest Control, Michigan Commission of Agriculture, Lansing, MI, provides general guidance on agricultural pesticide use. These GAAMPs describe information on applicator certification, application equipment, methods and record keeping, pesticide handling and safety, and disposal of excess spray mixtures, unused pesticides and pesticide containers. Instructions on the pesticide label must be followed; they are the law. Pesticide applicator certification is required to purchase or apply restricted use pesticides. Certification is recommended for all persons applying pesticides. Pesticide users also must comply with the Federal Worker Protection Standards. Keeping accurate records of pesticide applications is essential for farm planning and performance evaluation. Some considerations in pesticide use that are specific for cranberries are discussed below.

- **Understand alternatives to pesticide, which are available for the crop to be grown.**
  The options for pest management in agricultural crops include non-chemical and chemical control. The pesticide user should consider alternatives and make conscious decisions concerning pesticide use which evaluate potential site contamination, pest management, and economics of use. Non-chemical means of control include sanding, flooding and biological controls including Bts, nematodes, etc.

- **Calibrate application equipment properly.**
  Proper calibration ensures equipment is delivering the correct amount of pesticide and applying it uniformly over the target area. Over-application creates needless risks to water resources and increases economic inputs and must be avoided. Under-application will result in inadequate control and economic loss.

- **Develop a plan to follow in case of pesticide emergencies.**
  Pesticide applicators should develop an emergency plan which lists actions to take and persons to contact in case of pesticide poisoning, spill, fire, or other accidents. Compliance with SARA Title III regulations is described in MSU Extension Bulletin E-2175.

- **Keep pesticide applications out of surface waters by avoiding over-spray and drift.**
  Prevent non-target application by shutting off sprayer when boom or mist blower crosses ditches or waterways. In most cases, label language prohibits application directly to open or surface waters. Follow label guidelines regarding wind speeds and equipment requirements in order to direct applications to the target. Application of

pesticides during excessive wind (greater than 5 mph) causes unnecessary non-target application, reduces uniformity of the application, and reduces pesticide efficacy. Use anti-drift agents when appropriate. Regardless of application method, every effort should be made to keep pesticides confined to the bed and out of open or running water.

- **Consider the vulnerability of water and other natural resources when making pest management decisions.**
  The risk of inadvertent contamination of surface and groundwater resources differs for each farm. Pesticide users should include the risk to water resources as criteria of pest management decisions. The potential for contaminating groundwater is influenced by soil characteristics, depth and type of bedrock, and depth to the water table.

- **Apply pesticides only as needed.**
  When making pesticide applications use the lowest effective rate. IPM allows for better management of pest problems. IPM can provide information on pest populations that allows spot treatments and improves timing of treatments. These two strategies can lead to a reduction in overall use due to increased efficacy and earlier control.

- **Hold water containing pesticide residues for required or recommended times.**
  Holding water in ditches allows for degradation and dissipation of pesticide residues. All waters in contact with the beds must be retained for the length of time required by the label and, ideally, held as long as practical to allow maximum degradation. Low water levels in ditches prior to application increases the water holding capacity of a bed.

- **When aerial applications of pesticides are made on beds adjacent to or near a road or highway, consider using flag people to control or stop traffic flow during application.**
  Inadvertently spraying pesticides on motor vehicles traveling on public roads is illegal and will initiate an investigation by the MDA. Repeated occurrences could jeopardize continued availability of aerial pesticide applications. Posting of flag people to stop traffic along both approaches to the bed, prior to a pesticide application, will minimize the incidence of accidental exposure.

- **When chemigating, make sure your system complies with federal and state laws.**
  Label instructions must be followed when applying chemicals through the irrigation system (chemigation). Pay particular attention to application, reentry, pre-harvest and water retention times. If an irrigation system is used to apply pesticides, it must be fitted with a check valve, low pressure drain, vacuum breaker, low pressure shutoff switch, and injection port on the discharge side of the pump. Pesticides cannot be legally introduced into an irrigation system through the suction side of the pump. Refer to MSU Extension Bulletin 2099 for chemigation techniques and compliance rules. Determine the amount of time it takes a pesticide to travel through an irrigation system

by injecting a dye into the system and monitoring its flow through the system with a stopwatch. This information is necessary to optimize pesticide performance. Pesticide will be left in the irrigation lines if the system is operated for less than the injection time, whereas running the system for too much time can result in pesticide being washed off the target area. Pesticide injection times of greater than 10 minutes may adversely affect pesticide performance.

Check your irrigation system and property before every pesticide application. Effective insect and disease control requires that the irrigation system performs satisfactorily. Confirm that main and lateral lines are not leaking and sprinkler nozzles are not plugged. Inspect the entire property to insure people or animals are not present at or near the pesticide application area. These procedures should be followed if the pesticides are applied by the grower or custom applicator. Inspect property after application to be sure all signs are properly posted and that there are no people or animals present or near the application site.

Chemigation should only be practiced when uniformity, as measured by Coefficient of Uniformity Test, exceeds 60 percent. Non-uniform application of pesticides can pose a serious environmental and food safety risk. Optimize irrigation system performance before using chemigation as a pesticide application technique. Use of part-circle sprinklers can be effective in keeping pesticides out of surface water and off dikes and travel lanes.

B. WEED MANAGEMENT

Weeds in cranberry beds need to be managed. Effective weed control usually requires the integrated use of chemical and cultural strategies.

- **Scout for weeds.**
  Weeds must be identified correctly in order to choose effective control measures. Several references listed at the end of these GAAMPs may be useful in identifying common weed species. In scouting, note the species, infestation severity, and location for future management decisions.

- **Use cultural practices where possible.**
  Sanding and hand weeding can be effective weed management practices, especially in young plantings. Weed competition can be reduced by maintaining a low soil pH and encouraging healthy, vigorous vine growth that competes with weeds.

- **Use herbicides judiciously and always according to label instructions.**
  Refer to university recommendations for specific suggestions on herbicide use.

Always read and follow label instructions and use the lowest effective rates. Consider bed conditions such as soil composition, weed pressure and species, and drainage in choosing herbicides and rates. Spot treat if possible. Use markers or dyes to double check where you have already applied herbicides. Apply herbicides when vines and beds are dry. Splitting applications of granular herbicides may result in better control and minimize off-site movement.

Herbicide application equipment should be calibrated annually or each time a new material is applied. Check for changes in output due to equipment wear. Ground equipment is the preferred method of granular application, providing uniform coverage and minimal off-target exposure. Understand the leaching potential of each herbicide.

- **Prevent weeds from establishing in beds.**
  Start with a clean weed free bed. Control weeds when they first appear and before they spread. For example, hand wipe or pull brambles, tree seedlings and dodder.

  Mow dikes and other adjacent areas to prevent weeds and weed seeds from moving into the bed.

C. INSECT MANAGEMENT

Various insect pests may infest cranberry beds and require chemical and cultural control practices in order to avoid crop losses.

- **Avoid resistance.**
  Repeated use of the same insecticide can rapidly select for resistance in certain insects and should be avoided by rotating insecticides used, integrating biological and cultural controls into management programs and reducing insecticidal inputs to a minimum. Spot treat whenever possible.

- **Predict insect infestations to increase scouting efficiency.**
  Heat unit accumulation models, migration prediction systems, pheromone and light trapping networks, and other predictive technologies should be used to maximize scouting efficiency, optimize timing of applications and improve pesticide decisions made by growers.

- **Protect natural controls.**
  Natural predators and parasites play an important role in regulating pest insects. Their role should be enhanced wherever possible by minimizing exposure of beneficial insects to disruptive insecticidal treatments. Beneficial insect populations can be encouraged by conservation and reduced reliance on chemical control practices.

- **Adopt biological controls that are effective alternatives to insecticides.**
  In cases where biological controls play a major role in regulation of pests in natural

systems, such controls should be utilized. When natural controls are present, these should be encouraged and protected to achieve maximum potential. In the absence of natural controls, parasites or predators may sometimes be introduced and successfully established.

- **Consider the environmental risk when selecting insecticides.**
When insecticide applications are needed, select products that will provide control and minimize the potential for adverse environmental effects. Factors such as risk to non-target organisms, toxicity, persistence and potential for contamination of ground and surface water should be considered. If the potential exists for adverse aquatic affects, consider less toxic compounds.

D. DISEASE MANAGEMENT

Cranberry diseases can be best managed by integrating cultural and chemical control practices. The susceptibility of cranberry vines to disease is often associated with the overall plant health and vigor, as well as environmental and cultural conditions. The strategies and practices below may help increase disease resistance in the plant and make conditions in the bed less favorable for disease development. Optimum integration of several of these practices, where appropriate, will help manage diseases with minimal chemical input and environmental impact in an economically feasible and profitable way.

- **Growers should be familiar with disease symptoms and pathogen biology.** Refer to references in Appendix I for information on cranberry disease diagnosis and life cycles. Beds should be scouted regularly to determine disease presence and severity. Make sure the disease is correctly diagnosed before deciding on control measures.

- **Optimize nutrient practices to increase disease resistance in plants.**
Plants that are stressed by inadequate nutrition may be more susceptible to some diseases. Also, excessive nitrogen can result in rank vine growth that is susceptible to pathogen attack. Overgrowth often results in increased humidity and extended vine wetness which encourages pathogen activity.

- **Adopt cultural disease control practices.**
Cultural practices aimed at removing or disrupting pathogens should be employed when feasible. The practice of sanding buries pathogen infested duff and proper disposal of trash piles following harvest removes inoculum. In some regions spring floods can effectively disrupt pathogen activity. New beds should be planted with vines from healthy beds or plug plants, using disease tolerant varieties where practical. Reduce soil, water and plant material movement from diseased beds to non-infested beds in order to limit the spread of pathogens.

Plants stressed by too little water, over watering, and/or poor drainage may be more susceptible to pathogen attack and disease development. Practices that improve drainage where needed and minimize the time during the growing season when plants are wet should be considered. Optimizing irrigation system uniformity will improve drought management, reduce freeze damage due to inadequate frost protection, and improve disease control where chemigation is practiced.

- **Optimize uniformity of fungicide applications**.
  The degree of disease management with fungicides is highly dependent on uniform application coverage. Enhance disease management by making cost effective improvements to application systems where needed to optimize uniformity of coverage across the bed and on the target plant parts. For each of your chemical application systems used to apply fungicides, determine and use the optimum amount of water, pressure, injection timing, etc. needed to obtain desired product application.

- **Optimize number and timing of fungicide applications.**
  For most fungal diseases in cranberries, control is best or only obtained by preventing initial attack by the pathogen. Understand life cycles and the influences of weather, and apply protective fungicides only during infection periods. Complete control is not always needed or cost effective, so only make applications when the fungicide provides substantial economic benefit.

- **Choose fungicide and formulation best suited to the current target problem.**
  A steady increase or a noticeable change in disease problems over a few years may indicate a need to change fungicides or rates to better manage fungal populations. Pathogen populations and activity change from year to year for many different reasons, so fungicides may lose effectiveness. Choose the fungicide that will provide adequate control but is also the most cost effective and environmentally compatible. Choose formulations best suited for your application system. Use less persistent, but effective, fungicides late in the growing season to reduce fungicide residues on fruit. Use the lowest effective fungicide rate.

E. WILDLIFE MANAGEMENT

Gates and fencing may be needed to control access to cranberry operations and reduce deer damage and, in some cases, vandalism and theft by humans. Muskrats and other burrowing animals need to be monitored and controlled since they damage dikes and roads. Contact the Michigan Department of Natural Resources for regulations regarding trapping. Noisemakers, projectiles and other scare devices may be used to minimize damage from all forms of wildlife, as warranted.

Section VII. POLLINATION

Cranberries require bees for pollination. During the bloom period (mid-June to mid-July), honey bee hives are placed in the production area. One or more hives should be used per acre of cranberries. Insecticides that may harm bees should not be applied during bloom. Bumble bees may also be used for pollination.

Section VIII. PRUNING

Vines should be mechanically pruned periodically to remove excessive growth and encourage upright production. Vines removed during pruning may be sold or used to establish new beds or renovate less productive beds.

Section IX. HARVESTING

Cranberries should be harvested when they have met the proper maturity indices (primarily color). Harvest will be from late September through October.

- **Flood harvest.**
  Berries to be sold for processing are generally harvested by flooding the beds and mechanically removing the berries. The berries float and are corralled to one side of the bed and removed by elevators or suction pumps. When flooding for harvest, flood as quickly as possible without causing bed erosion. Harvesters should contain food grade hydraulic oil and each harvester must have an oil containment kit and the operator instructed on how to properly use it. Flood water should be pumped or drained slowly after harvest is complete. Trash collected from beds at harvest should be removed from the planting area to reduce disease inoculum.

- **Dry harvest.**
  Berries sold for fresh consumption are generally dry harvested. Typically, berries are mechanically removed from the plants, placed in bins and removed from the bed for cleaning and storage. Dry harvested beds may be flooded after the berries are removed so the trash can be floated off. This sanitary practice removes diseased fruit and vegetation, and reduces the disease pressure the following season. All flood water should be released slowly to minimize erosion.

Section X. SANDING

- **Cranberry beds should be sanded every two to five years.**
  Sanding encourages growth and suppresses some insect pests and diseases. Sanding on top of the ice is preferred to applying sand in water since ice sanding usually provides a more uniform application. Ice sanding may also have less environmental

impact because the water is usually held for sufficient time to allow silt-sized particles to settle out before water is discharged. Always release flood waters slowly.

Section XI. NEIGHBOR TO NEIGHBOR RELATIONS

U.S. Census data indicates people are leaving urban population centers for suburban and rural areas. Some people move to rural areas with certain expectations that conflict with agricultural practices. Several management practices listed here can be helpful in maintaining good relations with your neighbors.

- **Keep your cranberry farm and adjoining property clean and free of debris.** A clean and well managed cranberry operation demonstrates pride of ownership and portrays a high level of professionalism to outsiders, whether it be residential neighbors or regulatory agency personnel. If stockpiles of pipe, culverts, and equipment parts must be maintained, try to keep material orderly and not in view.

- **Communication is the key to good neighbor relations.** Effective communication with neighbors helps prevent and resolve problems. Inform neighbors about all aspects of cranberry production. Consider hosting tours around a social event or to observe harvest. This gives you the opportunity to explain cranberry growing firsthand. Once your neighbors have a better understanding of what you do, they are more comfortable with your activities. It also gives you the opportunity to hear their concerns and develop positive relationships with them.

- **Explain to neighbors the importance of safe and ecologically sound crop management practices, including IPM, pesticide use, and the importance of adhering to pesticide notices and sign posting. Be selective in crop management practices and evaluate the human and environmental risks associated with their use.**

- Be sensitive to concerns of neighbors. Be aware there are strong odors associated with certain pesticides. Post your property with appropriate signs prior to pesticide applications. Consider notifying neighbors before pesticide applications.

Much of the information in this document was derived from the Wisconsin State Cranberry Growers' Association, "Cranberry Grower Resource Notebook" of March, 1995, and "Standard Agricultural Practices for Cranberry Production in Wisconsin" of February, 1992.

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APPENDIX II. PERMITS AND REGULATORY CONSIDERATIONS

AGENCIES: Prospective cranberry growers should have a general knowledge of the programs and responsibilities (in administering federal and state laws) of federal and state agencies that may be involved in cranberry related activities. Prior to establishing a cranberry production site, producers should consult with the Land and Water Management Division of the MDEQ and all other appropriate agencies to determine if any permits are required. All required permits need to be obtained prior to initiation of any regulated activities, such as, construction of cranberry beds and associated facilities.

STATE

Michigan Department of Environmental Quality (MDEQ) has the key regulatory and program provisions on wetlands and administers what is commonly known as the Wetlands Protection Part, Inland Lakes and Streams Part, etc. of the Natural Resources and Environmental Protection Act. This authority was granted to the MDEQ by the State Legislature. MDEQ also administers Section 404 of the Federal Clean Water Act in the non-coastal areas of Michigan through a Memorandum of Agreement with the U.S. EPA. Permit applications for work in regulated wetlands, lakes, streams or floodplains are submitted to the MDEQ's Land and Water Management Division.

Michigan Department of Agriculture (MDA) administers the Soil Survey Act, Conservation Districts Act, Michigan Right to Farm Act, Michigan Drain Code, Fertilizer and Pesticide Control Act, and others, and is responsible for assembling agricultural statistics and promoting agricultural development in Michigan. The MDA is involved in a joint effort with the MDEQ to

ensure consistency regarding the administration of the Memorandum of Agreement (MOA) on Cranberry Production and Environmental Protection between the two departments. One should begin with the Environmental Stewardship Division and then the MDA Office of Agriculture Development on issues. One function or purpose of the MOA is to ensure that staff of both agencies receive clear guidance or direction on how to make decisions relative to the establishment of a cranberry industry in Michigan.

FEDERAL

Army Corps of Engineers (COE) is the permitting authority for Section 404 of the Clean Water Act, except as modified by the Michigan administration of the 404 program.

Environmental Protection Agency (EPA) has veto authority over the COE decisions and is the lead agency for the Clean Water Act.

U.S. Department of Agriculture: Three USDA agencies may be useful in cranberry issues. The Natural Resources Conservation Service (NRCS) is the lead agency for soil surveys and soil information, such as, prime, unique and important agricultural land. NRCS also provides highly erodible land and wetland determinations for purposes of USDA program eligibility. NRCS also provides direct technical assistance to landowners to develop and implement their conservation plans. The Farm Service Agency (FSA) is responsible for providing, filing and maintaining the official copy of the land determinations provided by the NRCS. They use this and other information to identify farms and land areas suitable for different uses. FSA also provides loans and grants as per Farm Bills and Farm programs. Rural Development (RD) is responsible for providing financial assistance to rural businesses and both financial and technical assistance to cooperatives. RD may consider the market value of brand names, patents or trademarks.

U.S. Department of Interior, Fish and Wildlife Service (FWS) has an advisory role in the permitting process and mitigation decisions.

STATE WETLAND PERMIT PROGRAM. The construction of commercial cranberry farm operations in Michigan will typically include activities which are regulated by the Land and Water Management Division, MDEQ under the Natural Resources and Environmental Protection Act, P.A. 451 of 1994, as amended. More specifically, Part 303 - Wetland Protection requires that an individual acquire a state permit for work in any regulated wetland. Wetlands are defined as "land characterized by the presence of water at a frequency and duration sufficient to support and that under normal circumstances does support wetland vegetation or aquatic life and is commonly referred to as a bog, swamp, or marsh." Regulated wetlands include any of the following:

- wetlands located within 500 feet of other surface waters, or within 1000 feet of the Great Lakes, regardless of wetland size;

- isolated wetlands larger than 5 acres in those counties having a population greater than 100,000 or having a completed wetland inventory;

- other wetland areas deemed essential to the preservation of the natural resources of the state, in this last instance with the acted provision that the property owner must be so notified.

A state wetlands permit will generally be required for work in regulated wetlands and includes any grading, filling, drainage, construction of dikes, ditches, or reservoirs, or placement of other structures within the wetland area. Michigan Resources Inventory (MIRIS) land classification maps, including wetland designations, are available in about 20 county offices. The U.S. Fish and Wildlife Service has developed wetland inventory maps for all of Michigan, and the USDA Natural Resources Conservation Service made soil surveys and land determinations in most of Michigan for 1996 Farm Bill purposes only. Although these sources may be helpful initially in identifying wetlands, the MDEQ has authority to make final designations based on site visits.

OTHER STATE PERMITS. In addition to a wetland permit, Part 301 - Inland Lakes and Streams requires that an individual obtain a permit for construction of upland reservoirs, construction of stream crossings, placement of water control structures or for alteration of lakes and streams, as defined by the statute.

An individual planning a cranberry farm operation should be aware that construction permits may also be required under the Flood Plains (Part 31) and the Dam Safety (Part 315) provisions of Act 451. The Land and Water Management Division MDEQ utilizes, for a state permit, a single application form for review under the various parts of the statute. A separate and different application would be needed for an endangered species permit. In addition, depending on the operation of the facility, there may be reporting requirements for withdrawal of water under provisions of the water use reporting authority of Part 327 of Act 451. Additional state permits may be required for discharge to a surface water or impact to a listed threatened or endangered species.

Discharges of runoff containing pesticides or nutrients into waters of the state is a violation of Section 3109 of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended. Section 3109 states: "A person shall not directly OR INDIRECTLY discharge into the waters of the state any substance that is OR MAY BECOME injurious to any of the following: (a) To the public health, safety or welfare, (b) To domestic, commercial, industrial, agricultural, recreational, or other uses which are being or may be made of such waters, (c) To the value or utility of riparian lands, (d) To livestock, wild animals, birds, fish, aquatic life or plants or the growth or

propagation thereof be prevented or injuriously affected; or whereby the value of fish and game is or may be destroyed or impaired".

Waters of the state" means groundwaters, lakes, rivers, and streams and all other watercourses and waters within the jurisdiction of the state and also the Great Lakes bordering the state. Section 3115 of 1994 PA 451, as amended, allows the MDEQ to request the Department of Attorney General to seek remedies for violations of Act 451. The court shall impose a civil fine of not less than $2,500 and not more than $25,000 per day of violation.

FEDERAL Section 404 PERMIT PROGRAM. In addition to the State permit requirements for impacting surface waters and wetlands, Section 404 of the Federal Clean Water Act regulates placement of fill in waters of the United States, including wetlands. In most states, a permit must be obtained from the U.S. Army Corps of Engineers (COE) for dredge and fill activities which would result in the placement or redistribution of material in wetlands and other waters. In 1984, the U.S. Environmental Protection Agency (EPA) authorized Michigan to administer the Federal Section 404 program in most areas of Michigan. In those areas of the state where Michigan has Section 404 authority, a state issued inland lakes and streams or wetland permit also authorizes activity under the Federal Clean Water Act. Michigan's Section 404 program is required to meet Federal Clean Water Act standards as long as Michigan administers the Federal permit program. Action taken under a state-assumed Section 404 program is a state action taken under state law, not a federal action. MDEQ may not issue a permit which carries Section 404 authority if the EPA objects to the project.

The COE has retained Section 404 jurisdiction over traditionally navigable waters including the Great Lakes, connecting channels, and other waters connected to the Great Lakes where navigational concerns are maintained. The COE also retained Section 404 jurisdiction in wetlands directly adjacent to these waters. Therefore, in Great Lakes coastal areas and adjacent wetlands, both state and federal permits are required for dredge and fill activities within wetlands and surface waters. To avoid confusion to the permit applicant, the Detroit District COE and MDEQ follow a joint application process which utilizes the same application form. The application is submitted to MDEQ which forwards copies of the application to the COE if there is separate federal jurisdiction. Application forms and additional information on materials to submit with the application for a proposed cranberry farm operation can be obtained from the Land and Water Management Division, MDEQ.

THE MICHIGAN RIGHT TO FARM ACT, P.A. 93, 1981, as amended, notes the following MCL 286.473, Section 3(3) "A farm or farm operation that is in conformance with subsection (1) shall not be found to be a public or private nuisance as a result of any of the following:

(a) A change in ownership or size.
(b) Temporary cessation or interruption of farming.
(c) Enrollment in governmental programs.

(d) Adoption of new technology.
(e) A change in type of farm product being produced."

THE FEDERAL FARM BILL

The 1935 Farm Bill is an act to provide protection of land resources from soil erosion and sedimentation, and also protect water resources. In 1977, USDA's OGC reinterpreted the 1940 Presidential reorganization, permitting the Soil Conservation Service, presently the NRCS, to work on Tribal Lands situated within boundaries of a conservation district. In 1980, the USDA extended conservation assistance to Indians on Tribal lands. The 1985 Farm Bill (Food Security Act of 1985), as amended by the 1990 Farm Bill (Food, Agriculture, Conservation and Trade Act of 1990), the 1996 Farm Bill (Federal Agriculture Improvement and Reform Act of 1996) and the 2002 Farm Bill (Farm Security and Rural Investment Act of 2002) addresses producer eligibility for USDA programs, such as the Conservation Security Program (CSP).

Proposed cranberry production on existing wetlands will be exempted for USDA program benefit eligibility as a Converted Wetland for Non-Agricultural purposes (CWNA). This exemption will require that a CWNA plan be developed and filed with the Natural Resources Conservation Service (NRCS). An application for an exemption must be submitted to and approved by the local NRCS office before conversion activities begin. The area will then be labeled CWNA and recorded on the USDA Farm Services Agency aerial photography.

Cranberry production is allowed on prior converted wetlands as defined in USDA Farm Bill legislation. Prior converted wetlands (PC) are wetlands that were drained, dredged, filled, leveled, or otherwise manipulated, including the removal of woody vegetation, before December 23, 1985, for the purpose of, or to have the effect of, making the production of an agricultural commodity possible, and an agricultural commodity was planted or produced at least once prior to December 23, 1985. Prior converted wetlands converted before December 23, 1985, are exempt from Farm Bill and Clean Water Act (CWA) provisions. In some cases, the US Army Corps of Engineers may consider “abandoned” Prior Converted areas as jurisdictional wetlands and a permit could be required. “Abandonment” means that no commodity crop has been produced for five years or more and wetland conditions have returned.

APPENDIX III. CRANBERRY SITE REQUIREMENTS

The three basic considerations in choosing a suitable cranberry site are climate, soils, and water. We will discuss these items separately, although they are related to some degree. The climatic considerations can be discussed on a regional basis. However, the suitability of a specific location is based primarily on the soil and water characteristics. Since these characteristics are very site specific, we will discuss soil and water requirements in a general sense.

Climate

The American cranberry is native to Maine and Nova Scotia, west to Minnesota, and as far south as Virginia and Tennessee. This represents a wide range of climatic conditions. Commercial production areas also vary enormously, from the moderated marine climates of western Oregon and Washington to the harsh continental climate of central and northern Wisconsin. The suitability of Michigan regions for cranberry production can be assessed by comparing the climate to perhaps the harshest production area, Wisconsin.

There is little doubt that most of Michigan offers suitable climate. Cranberries have been successfully grown experimentally and commercially in the severe conditions of the Upper Peninsula. In most respects, the climate in southern Michigan is less challenging.

Minimum Winter Temperatures

Cranberry leaves and buds are subject to cold injury during the winter. Generally, midwinter temperatures below 10F will injure plants and higher temperatures may cause injury if accompanied by wind. Since these temperatures are common in Wisconsin, Massachusetts and New Jersey, bogs in these states are typically covered during the winter with a protective layer of ice.

The USDA Hardiness Zones reflect primarily average minimum winter temperatures. Cranberry production regions range from Zone 3 (N. Wisconsin) to Zone 9 (Pacific Northwest). Michigan falls between these extremes (Zone 4 in the Western U.P. to Zone 6 in Southwest Lower Michigan).

The fact that Michigan winters are more moderate than those in Wisconsin, presents some questions about winter protection. Wisconsin growers are able to maintain ice on beds throughout the winter. Southern Michigan frequently experiences "winter thaws", when ice cover would likely be lost. Beds would periodically need to be re-flooded to form new ice. Southwest Michigan also receives more snow than production areas of Wisconsin, which could impede ice formation and cause oxygen shortages beneath the ice. Growers in this area may need to develop winter protection strategies more similar to those in Massachusetts or New Jersey than Wisconsin.

It is not clear whether the low growing degree day (GDD) totals in the U.P. might affect cranberries. Plantings in northern Wisconsin apparently yield slightly lower on average than plantings in southern areas of the state. Perhaps this is related to differences in growing degree days. We do not expect low GDD totals to be a serious problem, even in cooler parts of the Upper Peninsula. A recently renovated commercial planting on Whitefish Point, which likely received less GDDs than any other area of Michigan, will provide useful information in future years.

Soils

Most traditional cranberry sites are on two general soil types - acid organic soils or poorly drained mineral soils with high organic matter content surfaces. The properties of these soils include a pH of 3.5 to 5.0 in the surface and a water table at 6 to 12 inches during the growing season. These traditional sites are easily converted and have adequate water. The disadvantage of these soils is that they are wetlands with

surface water systems, and their development requires permitting. The following characteristics of traditional cranberry sites are fundamental plant requirements:

1. Surface Texture - usually a peat or muck organic soil surface or sandy mineral soil with a high percentage of organic matter.

2. Depth - greater than 40 inches to bedrock.

3. Slope - 0 to 2 percent.

4. Water Table - ranges from 1.5 to 3.0 feet during the growing season (generally poorly drained or very poorly drained soils).

5. Reaction - surface horizon pH of 4.0 to 5.5.

Some cranberry operations have recently been developed by modifying non-traditional sites so that the basic requirements above are met. This approach has been taken to avoid wetland and water use regulations, and because these sites are readily available in some areas. Other non-traditional soils have been proposed for cranberries, but they have not been tested. It is important to recognize that although several basic non-traditional sites have been proposed, the basic requirements listed above need to be met in order to successfully produce cranberries. This may require significant additional development costs. We have categorized non-traditional sites into two alternatives:

- **Somewhat poorly drained and moderately well drained sands with regional water tables**

  These soils have sandy surfaces with varying amounts of organic matter, pH of 4.0 to 5.5 in the surface, and water tables one to three feet (somewhat poorly drained) to 2.5 to 6.0 feet (moderately well drained) during the growing season.

  An advantage of these soils is that they are not typically classified as wetlands. The major disadvantage is their high permeability, which could lead to problems maintaining desired water table levels or with movement of chemicals into groundwater. Several existing cranberry operations in Wisconsin have expanded into these upland sites.

- **Moderately well drained to poorly drained loamy or clayey soils**

  Properties of these soils include silty clay loam to clay surfaces with a pH of 4.5 to 6.5. Soils often become calcareous within 36 inches and have water tables at depths of one to six feet (depending on drainage class) during the growing season.

  Advantages of these soils are that they are slowly permeable, and could be developed into "closed" systems where little water is lost to deep percolation. Some areas of the state have extensive acreage of these soils that are prior converted (i.e. idle farmland). Many are classified as disturbed wetlands, and their use would more likely be permitted than undisturbed wetland. These soils have been proposed by the Michigan Department of Natural Resources as potential cranberry sites. The main disadvantages are the costs of development. Clean sand would have to be brought in

as a rooting medium for the plants, and adequate water reservoirs would have to be constructed if surface water is not available.

- **Water**

  Cranberry production requires large amounts of water. Water is needed to protect plants against frost damage in the spring and fall. Traditionally, plantings were flooded before predicted frosts. Most growers now frost protect by sprinkling water on plants, since this requires much less water than flooding. Irrigation is also needed throughout the growing season to meet the water demands of the plants. Cranberry plants are shallow rooted and desiccate easily. Sprinkler systems may also be used to cool the plants during hot summer weather. Beds that are wet harvested are flooded in October with one foot of water to remove the berries, and a second one foot flood may be used to remove trash from the bed. Beds are again flooded with one foot of water in the winter to protect plants from winter weather.

  Actual water requirements vary with location and management practices, and are often expressed in acre-feet. One acre-foot is the water needed to cover an acre to a depth of one foot (about 330,000 gallons). Water use estimates range from 5.1 acre-feet in Maine, to six acre-feet in Wisconsin, and 7.8 acre-feet in Massachusetts. However, if beds and reservoirs are designed to recycle water, actual water use may be as little as 1.5 feet. This system would require an impervious soil substrata to prevent deep seepage losses of water, and a topographical layout that allows cycling of water from one bed to another and from beds to reservoirs.

Seasonal Water Need Estimates (acre-feet) for Cranberries

Time	Use	Maine[1]	Massachusetts[2]
April - May	Spring Frost Protection	0.5	1.7
June - August	Irrigation, cooling, chemigation	1.2	1.1
September - October	Fall Frost Protection	0.4	
October	Harvest Flood	1.0	2.0
October - November	De-trash Flood	1.0	
December	Winter Flood	1.0	2.0
Winter	2nd Winter Flood		1.0
	Annual Total	5.1	7.8

[1]Cranberry Agriculture in Maine Grower's Guide. Maine Cranberry Development Comm., 1993
[2] Massachusetts Cranberry Production. Univ. Mass. Coop. Ext. Serv., 1993

Acquiring and discharging water are prime concerns in selecting cranberry sites. Cranberry operations typically use surface water from existing sources (lakes, streams, drainage ditches) or from reservoirs. Access to water from lakes or streams may require permits. Construction of reservoirs of sufficient size may also require permits if they are located on existing wetlands. Wells typically do not have the capacity to supply the large volumes of water required at specific times. Well water may also be difficult to use for winter floods because it requires more time to cool and freeze. Wells can be used to replenish smaller reservoirs.

In addition, relatively large volumes of water may be discharged to drainage ditches, streams or lakes. Discharge may also require permits, since the temperature and chemistry of receiving waters can be affected.

- **Spring and Autumn Frost Potential**

  The average time between the last killing spring frost and the first killing fall frost defines the growing season. In natural environments, cranberries need about 150 frost free days to mature the berry crop. The growing season in cranberry production areas is longest in Oregon and Washington (280 days) and shortest in Wisconsin (110 days in some northern areas and 160 days in the south). The growing season in Michigan ranges from 100 days in the western U.P. to 170 days in southwest Lower Michigan. Cranberry growers protect against frosts and extend the effective growing season by sprinkle irrigating or flooding. However, production in short season areas will require more frequent frost protection and thus greater management costs.

  Precipitation/Evapo-transpiration: Irrigation Requirements
  Irrigation requirements are dependent on the amount of precipitation and evapo-transpiration or amount of water lost to the air from leaves and the soil surface. Annual precipitation in major production areas ranges from 30 inches in Wisconsin to 80 inches in parts of Oregon and Washington. Average annual precipitation in Michigan ranges from 28 inches in parts of the U.P. to 36 inches in southern Michigan. Warm-season precipitation (April-September) provides an indication of the need for supplemental irrigation during the growing season. Production areas in Wisconsin receive 20-22 inches between April and September, whereas warm-season totals for Michigan range from 16 to 22 inches. The lowest April to September totals in Michigan (16 inches) occur in the eastern U.P. and the extreme northern portion of the Lower Peninsula.

  The evapo-transpiration from cranberry bogs in Michigan would likely be similar to that of bogs in Wisconsin. Air temperatures and relative humidity, which largely control evapo-transpiration, are generally similar in Wisconsin and Michigan. Because water losses through evapo-transpiration and precipitation are similar, irrigation requirements are generally expected to be similar between the two states.

  Sprinklers are also used to cool cranberry plants during very warm days. High temperatures or dry winds early in the season may cause new growth to desiccate and "blast", whereas hot weather later in the season may cause scalding of the berries. Temperatures as low as 80F can injure plants in the normally cool Pacific Northwest, whereas 85F may cause injury under New Jersey conditions. Plantings in Michigan may require less water for cooling than plantings at similar latitudes in Wisconsin.

- **Heat Units and Growing Degree Days**

Temperatures during the growing season may have affected the growth of cranberry plants and fruit differently. Optimum temperatures appear to be 60-80F. Lower temperatures may limit yields by slowing growth and berry development. Higher temperatures can cause sun burning of berries during the summer, and inhibit color development if occurring during the fall. Growing degree days (GDD) are a measure of the heat accumulation during the season. Production areas in Wisconsin usually accumulate 2500 (north-central areas) to 3000 (central) GDD base 45F. The upper peninsula of Michigan typically accumulates 2300-2500 GDD base 45, and extreme southern Michigan sees up to 3800 GDD. On average, GDDs in the U.P. are slightly lower than those in even the cooler production areas of Wisconsin, and the GDDs in southern Michigan are comparable to those in southern Wisconsin.

APPENDIX IV. WATER BUDGET DATA SHEET

This worksheet addresses questions that should be considered for proposed cranberry sites. Each cranberry operation is unique in regard to the source of water, layout, etc., so only consider those questions that pertain to your operation (i.e., if your cranberry operation has a river as its water source, answer the questions under River/Stream and ignore those under Groundwater and Lake). Calculations, assumptions and sources of information also need to be provided.

I. DESCRIBE YOUR WATER SOURCE(S)

A. River/Stream

1. Use gauging data if available; if not available, provide best calculations based on drainage area, land use, etc., or data from a similar stream and watershed located as near as possible to the project site.

   Average annual flow in cubic feet per second (cfs)
   CFS flow and elevation for l00-year flood event
   7Ql0 flow (lowest 7-day flow in l0-year period)
   7Q2 flow (lowest 7-day flow in a 2-year period)
   Quantify the anticipated stream diversion, cfs /day, number of days.

2. Provide a map (to scale, l"= l,000=) showing that portion of the project area within the l00-year floodplain and/or floodway.

3. Cross-sectional drawing of the stream, upstream and downstream of the operation, showing water level at average annual flow and at 7Q2 and 7Ql0.

B. Lake/Reservoir

1. Describe the surface elevation, surface acreage and acre-feet (AF) of storage of the lake/reservoir during average, high water, and drought conditions.

2. Is the lake/reservoir isolated or connected to other lakes and/or river systems?

Describe. Provide map as appropriate.

C. Watershed Information

1. Size (acres or square miles)
2. Average slope of watershed
3. Characterize soils of the watershed (% peat, % sand, % clay, % impervious surfaces, etc.) using the county soil survey (if none has been prepared for your county, provide best available information).
4. Characterize watershed land use (% in upland forest, wetland, lakes, cranberry reservoirs, cranberry beds, other agriculture, urban, etc.)
5. If there are existing cranberry reservoir(s) on site, describe the distance from the project area, surface elevation, surface area, and AF of storage capacity during:
   a. Average conditions
   b. High water conditions
   c. Drought conditions (e.g., 1976 and 1988)

D. Groundwater

1. Average depth to water table
2. Describe springs and seeps (e.g., number, location, estimated flow (in gallons per minute (gpm), etc.)
3. Describe the permeability rate of the soil(s) involved at your site (refer to county soil survey information).
4. If reservoirs are to be constructed or enhanced, include the permeability rate of soils in the area. If a county soil survey is not available, take representative core samples to estimate permeability using methods similar to those utilized in soil surveys.

II: DESCRIBE HOW YOUR WATER SUPPLY SYSTEM WOULD WORK

A. What is the total water supply (in AF) combining river/stream, lake/reservoir and/or groundwater sources? What percentage would each contribute to your water supply?
B. If the proposal is an expansion of an existing cranberry operation, describe how the proposed expansion would tie in.
C. Identify discharge points on the site plan and for each indicate the frequency, duration, and volume (if more than one point, give percentages for each):

   1. Reservoir(s), (give estimated detention time for reservoirs used as temporary detention basins)
   2. Natural lake
   3. Stream/River
   4. Wetland complex

III. WATER USE

Precipitation, evapo-transpiration, and runoff amounts vary throughout Michigan. Data for specific locations can be obtained from the State Climatologists Office, Rm 417 Natural Science Bldg., Michigan State University, East Lansing, MI 48824 (phone: 517-355-0231). The average annual water use for cranberry production is 6 AF per acre of bed. Average annual precipitation ranges from 28 to 36 inches, and runoff from 6 to 21 inches.

A. Water requirements of your cranberry operation (acres of beds x 6 AF), both proposed and existing (if applicable)_____.
B. Estimate, in AF and percentage of total water use, how much water would be reused (i.e., pumped back into reservoir), during what time period.
C. Estimate how much water would be lost due to seepage.
D. Estimate AF of water discharged from the cranberry operation (i.e., to river or lake).
E. Complete a balance sheet of water sources (river, lake, reservoir, groundwater, net precipitation, etc.) and water uses (6 AF per bed, seepage, discharged outside of cranberry operation, etc.) for a one year period assuming average conditions.

IV. IMPACT ANALYSIS

A. River/Stream Water Source

1. Provide a water quantity analysis evaluating the in-stream impacts, both upstream and downstream, of withdrawing water for your cranberry operation.

2. Under a worst case situation, such as the drought of 1976 or 1988, what percent of the cfs flow of the river/stream would be diverted to your cranberry operation?

Use cross-sectional drawings similar to those in Part I.A.3. to show downstream water levels under average conditions and at 7Q2 with the proposed project in place.

B. Lake/Reservoir Water Source

1. How much would the surface elevation be lowered during the maximum short -term withdrawal (e.g., putting on the winter flood)?

2. If a reservoir (impoundment) is used, what is the distance and difference in elevation to the nearest occupied buildings located downstream and laterally

(adjacent to the reservoir) considering both those on your property and neighboring properties.

C. Groundwater Water Source

Describe the effect on the groundwater elevation due to proposed dikes, reservoirs, etc. (e.g., would the proposed reservoir raise the groundwater elevation? If so, how much?)

D. Summary

Describe how your water use could affect neighboring property owners (both upstream and downstream), wildlife refuges, recreational areas, public or private water supplies, other cranberry operations, and/or other agricultural users.

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